



United States Proposal for DART Buoy Deployments in the Indian Ocean

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NOAA/USA

NDWC Briefings

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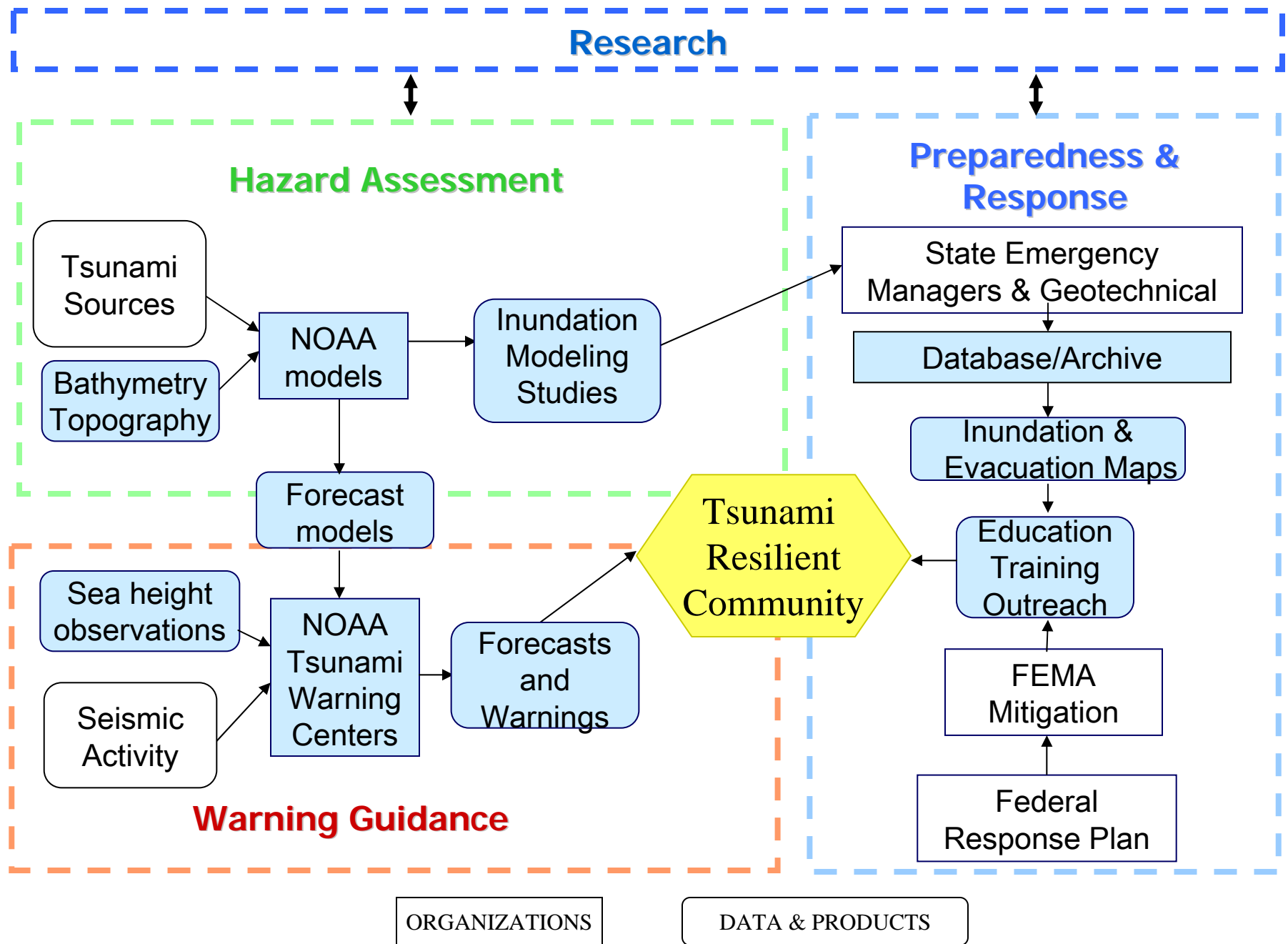


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Introduction/Purpose

- Improved warning times for tsunami events and the saving of lives
- The accelerated development of an “initial operating capacity” for the IOTWS
- Demonstration of U.S. and new IOC/ICG standards and protocols for moored deep ocean tsunami detection stations, and
- Development and operation of an end-to-end tsunami warning system for the Indian Ocean region, including providing a reference for future development of new government and commercial tsunami detection technologies



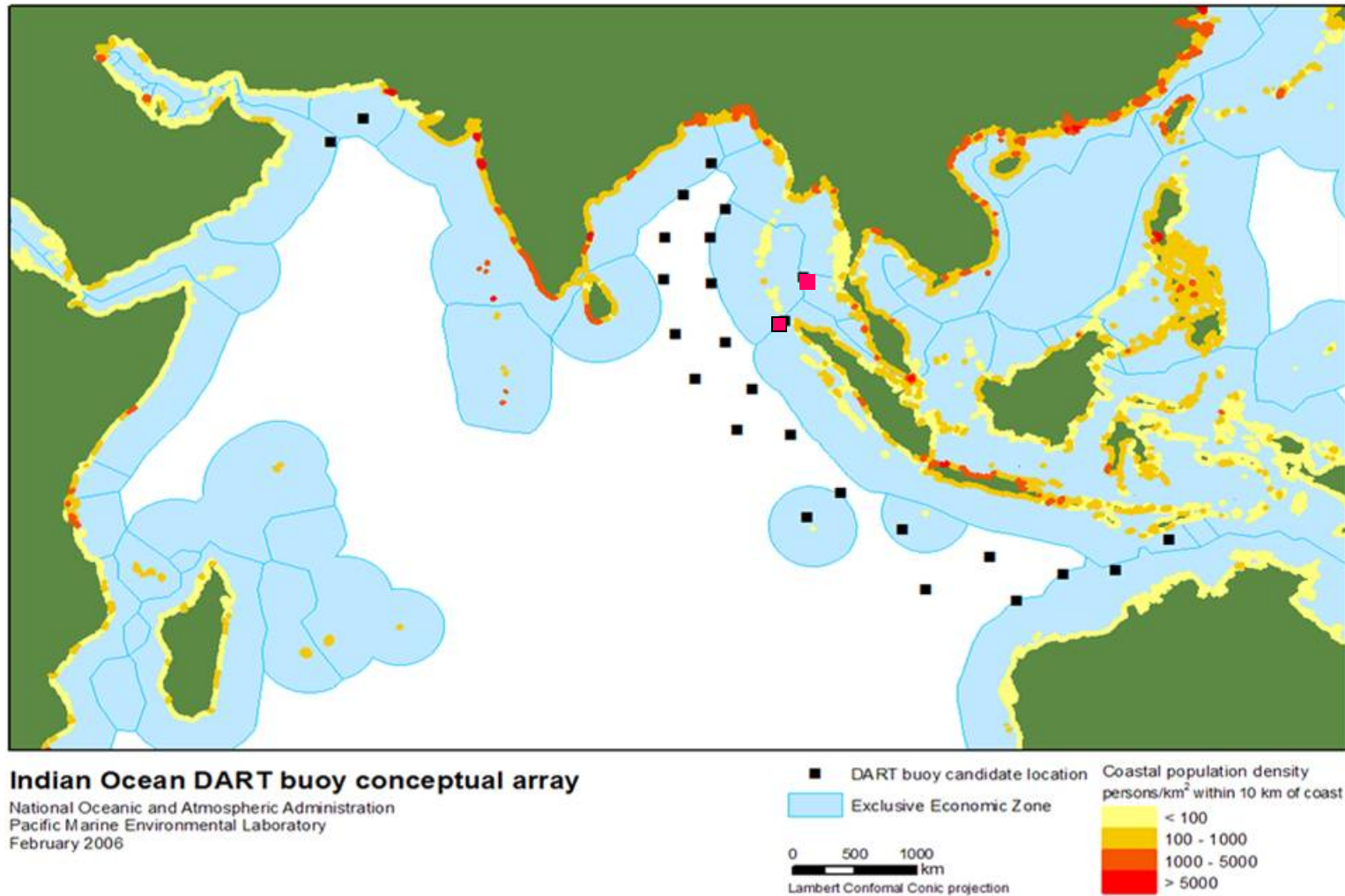
TARNS and Coastal Community Resilience Critical to System

- Hua Hin workshop advances Thai warning system
- Coastal Community Resilience strategic planning workshop designs integrated concept for disaster management, coastal management, and sustainable livelihoods
- These efforts are critical to NDWC and TMD success

Small Report Recommendations

- Based on Thai government plan for buoy array
- Based on requirement that buoys be deployed in Thailand's waters
- Station locations severely constrained by territorial boundaries and bathymetry
- Provided before additional analysis conducted at NOAA

Recommended Array from Small Report



Tsunami Detection Buoys for the Indian Ocean

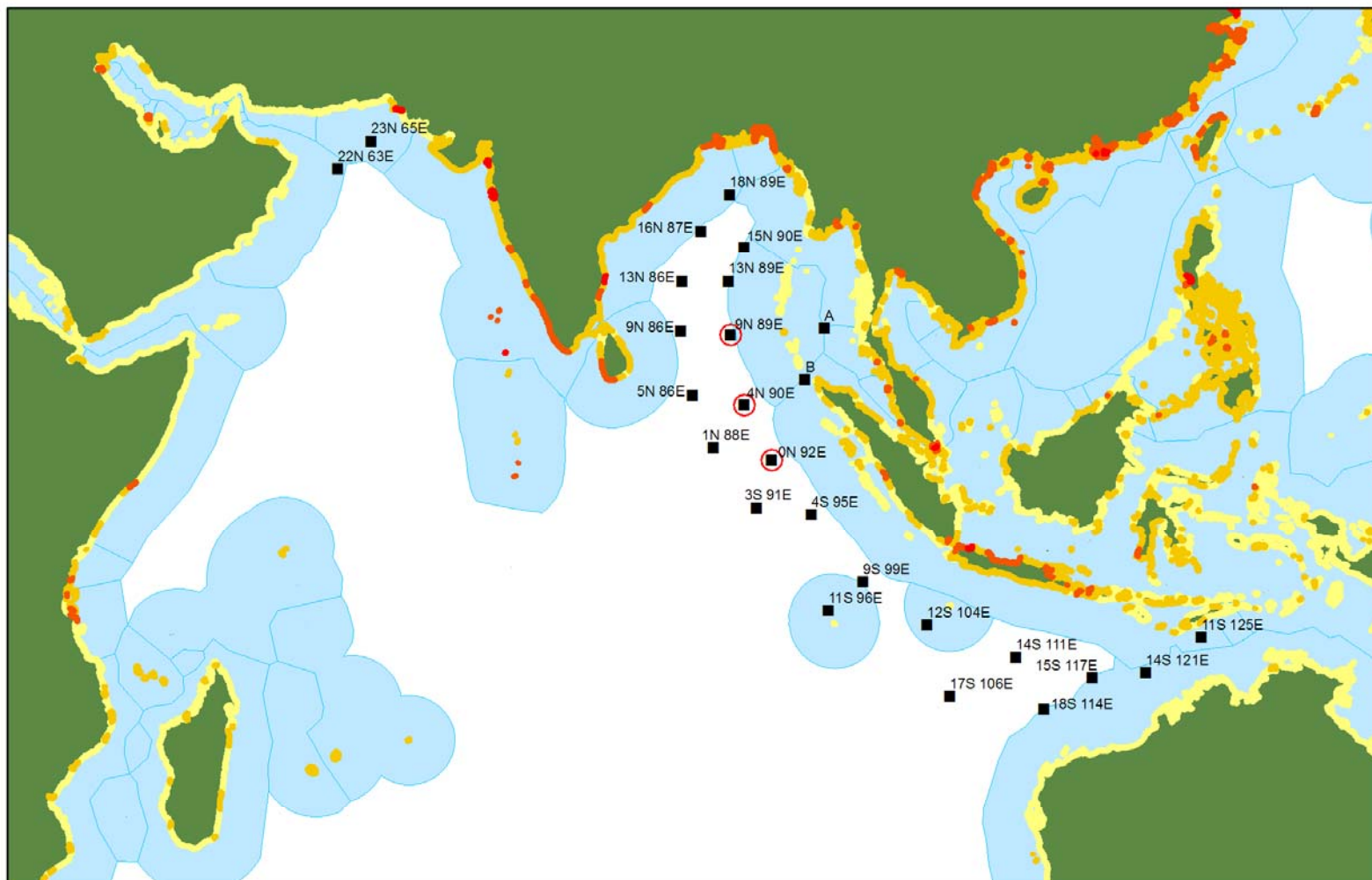
- Conceptual design presented in Perth Intergovernmental Coordination Group for the IOTWS (August 2005)
- “Small Report” offered to NDWC and TMD in March 2006 to review siting options and provide other information
- US Proposal submitted to ICG/IOTWS in Melbourne
- Thailand’s active engagement in IOC is critical

Reference Stations to Accelerate Development of the IOTWS

- validate ICG standards and performance requirements
- establish a baseline for comparison of simultaneous observations
- accelerate development of new tsunami detection designs and evaluate their performance in an operational context
- conduct intercomparisons between reference stations and other technologies for tsunami detection
- demonstrate functionality (e.g. triggering, data requests, diagnostics, distinguishing between actual events and false alarms from non-seismic events, instrument noise)
- record and evaluate broad spectrum oceanographic signals in the Indian Ocean
- conduct on-going training and capacity building.

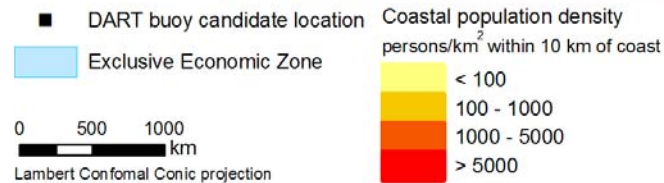
DART Deployment Considerations and Requirements

- Provide operational detection of tsunami (and verifications of non-events) in the Indian Ocean
- Contribute to the conceptual array for tsunami detection stations endorsed by the ICG/IOTWS
- Demonstrate the implementation of all IOC and NOAA standards and protocols for reliability, accuracy, interoperability, free and open exchange of data, and integration
- Demonstrate the operation of “core” IOTWS observation stations critical to a tsunami detection and forecasting system
- Contribute to the development and validation of new tsunami detection technologies
- Promote tsunami watch provider capacity for the IOTWS



Indian Ocean DART buoy conceptual array

National Oceanic and Atmospheric Administration
Pacific Marine Environmental Laboratory
April 2006



U.S. Constraints

- The U.S. provided a “conceptual array” of tsunami detection stations for the Indian Ocean (Perth, 2005) to ICG/IOTWS WG 2
- The U.S. has committed to provide two DART II warning and reference stations to support the IOTWS
- U.S. legislation requires that NOAA and other agencies supporting the IOTWS focus in five nations: India, Indonesia, Maldives, Sri Lanka, Thailand

Methodology

- NOAA conducted an analysis to determine which one or two stations in the conceptual array would, in general, provide the longest lead times for the five Indian Ocean nations
- This analysis refines the initial conceptual array by including population densities and major cities and exclusive economic zone boundaries
- The purpose of the analysis was to develop siting options for ICG/IOTWS discussion

Approach

- This analysis is an extension and refinement of the work NOAA did to develop the initial conceptual tsunami detection station array for the IOTWS
- It is not possible to generate precise potential warning times because of variables such as source location and strength, lack of a propagation model, and lack of complete geospatial data for the region
- The analysis includes sources along the Sumatra fault and the Sunda Strait
- This approach replaces the times (e.g. 30-60-90 minutes) provided in Perth with color-coded categories to show potential degree of warning time for particular locations.

Approach

- Pacific Tsunami Warning Center provided locations they use for analysis they conduct as part of their Indian Ocean interim notification responsibilities
- Only locations in India, Indonesia, Maldives, Sri Lanka, and Thailand are included.
- Analysis is based on the travel times of a wave from tsunamigenic sources from anywhere in the source region shaded in gray
- The analysis includes *potential* warning times the full conceptual array would provide and *potential* warning times for various one and two-station deployments.
- “Potential warning time” is based on time to detection. *Actual* warning times are less because transmission, analysis, warning formulation, and warning transmission times must also be considered

Illustration of Analysis: Different Energy Beams

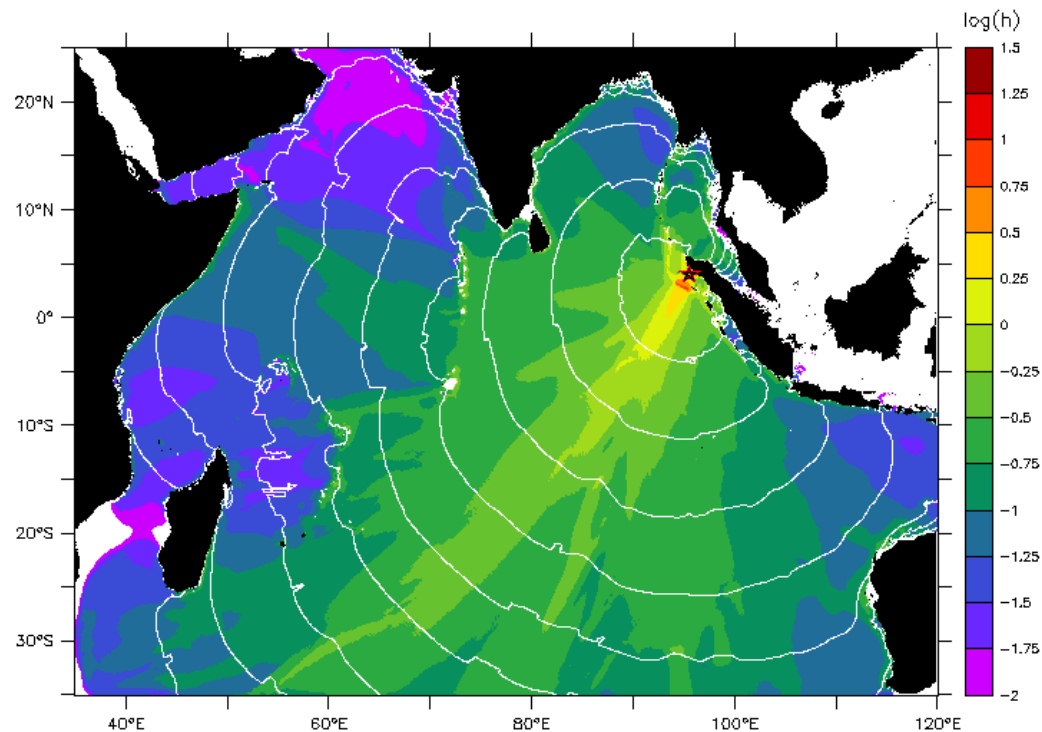


Illustration of Analysis: Different Energy Beams

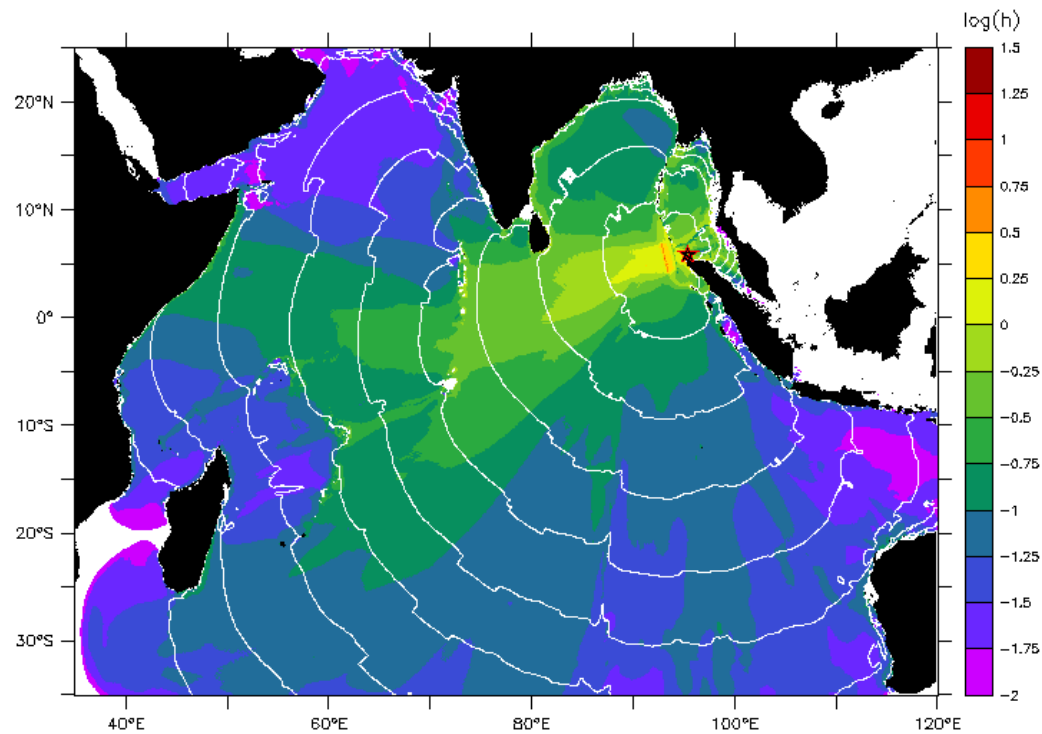


Illustration of Analysis: Different Energy Beams

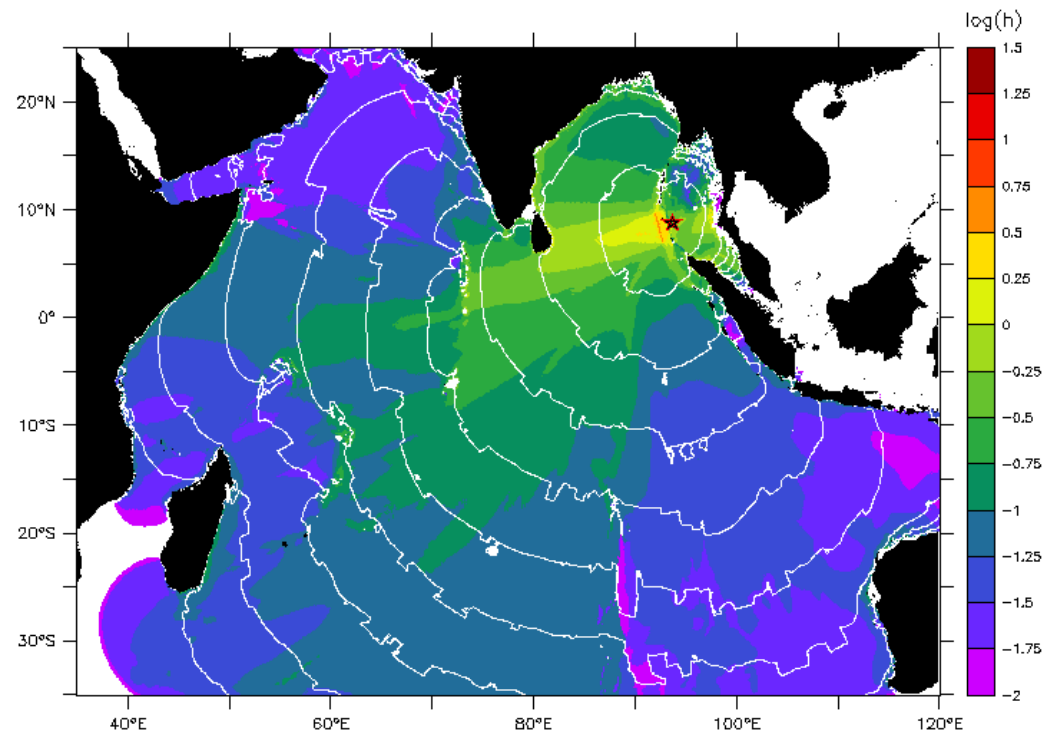
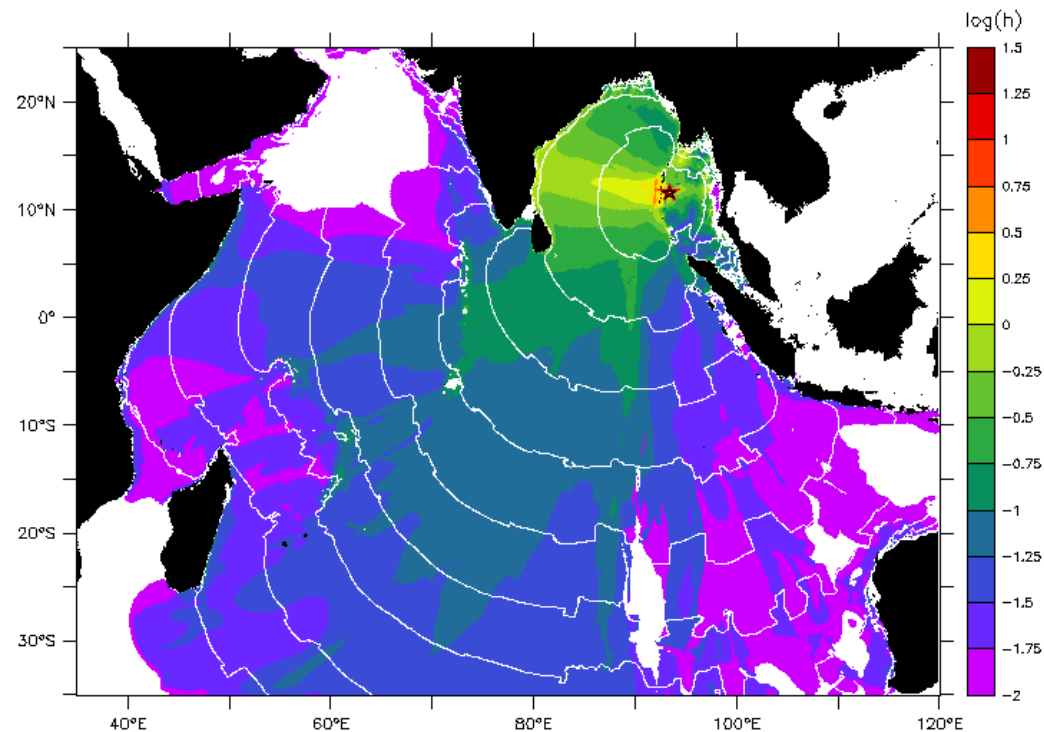
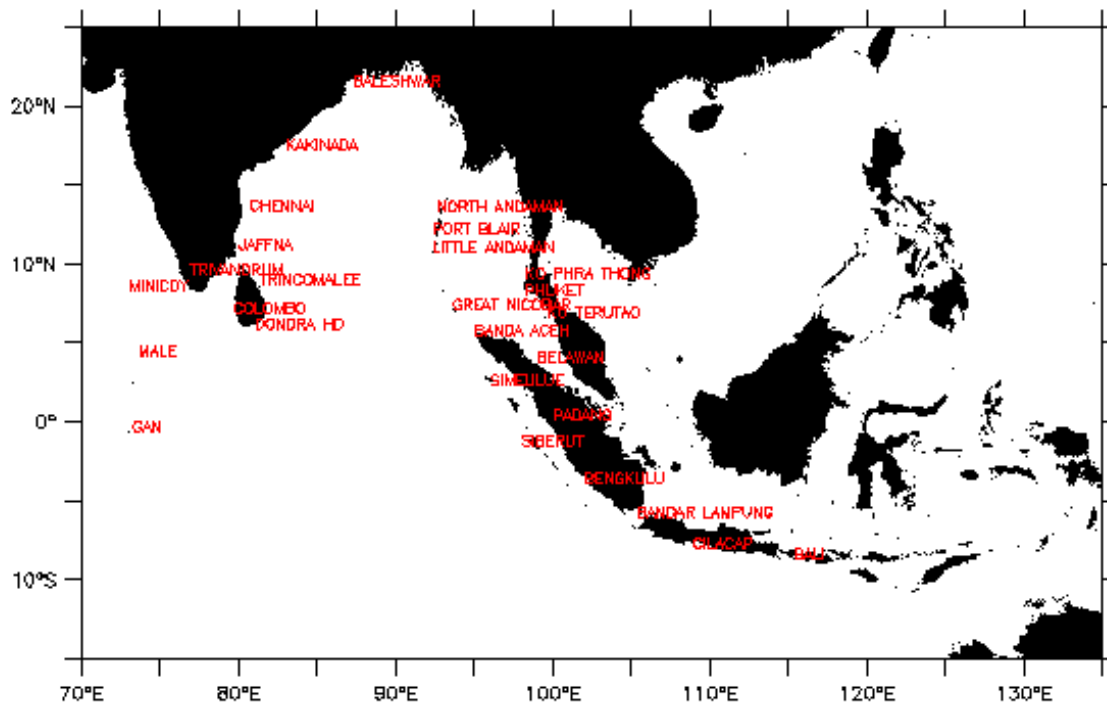


Illustration of Analysis: Different Energy Beams



PTWC Warning Locations

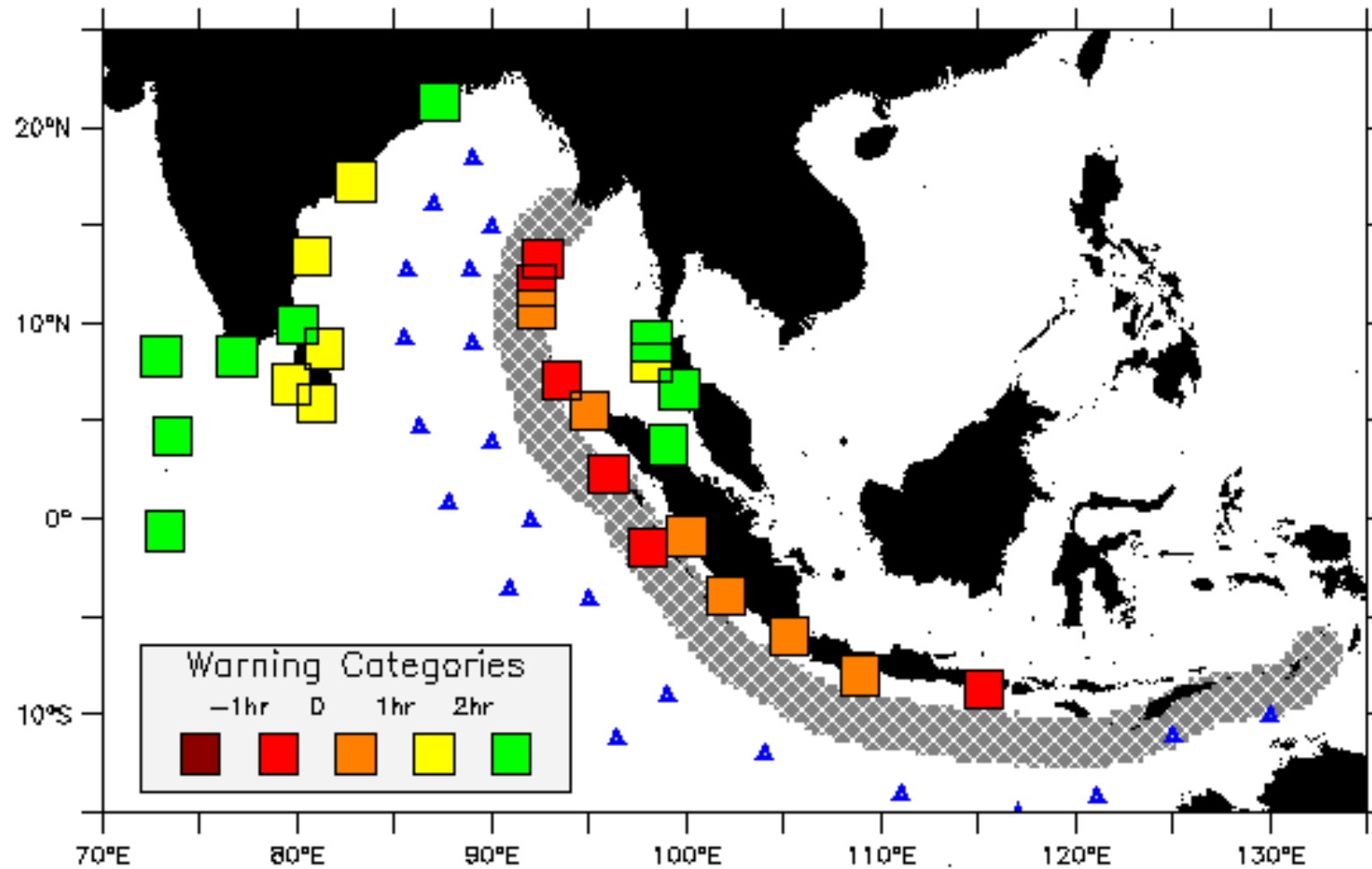


MALDIVES:	GAN MALE MINICOY
SRI LANKA	COLOMBO DONDRA HD JAFFNA TRINCOMALEE
INDIA	BALESHWAR CHENNAI KAKINADA TRIVANDRUM GREAT NICOBAR LITTLE ANDAMAN NORTH ANDAMAN PORT BLAIR
THAILAND	KO PHRA THONG KO TERUTAO PHUKET
INDONESIA	BALI BANDA ACEH BANDAR LAMPUNG BELAWAN BENGKULU CILACAP PADANG SIBERUT SIMEULUE

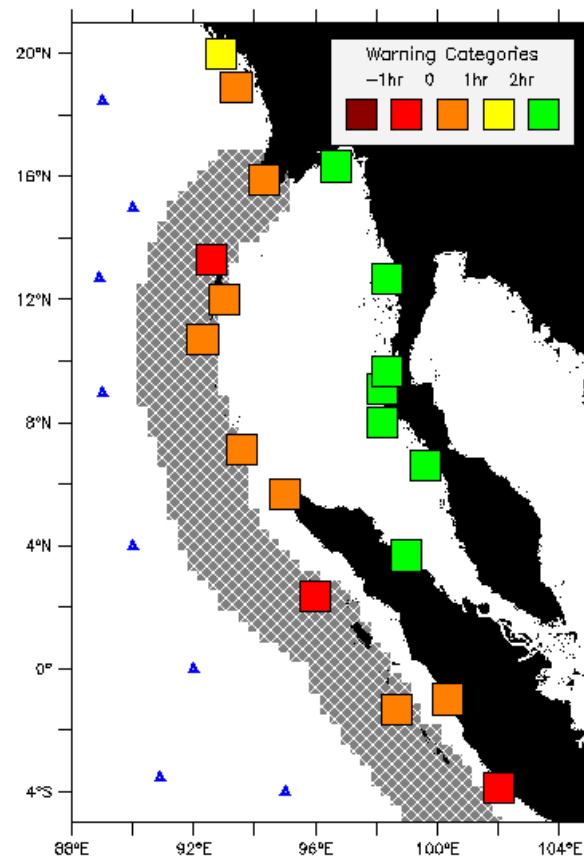
Explanation

- Blue triangles represent tsunami detection stations
- Colored squares overlay PTWC warning locations and indicate approximate potential warning times
- **Dark red** shows where the warning may be too late
- **Red** shows where the array provides critical information about successive waves
- **Orange**, **yellow**, and **green** show progressively better positive potential warning times
- Note that for the full array, all locations receive at least data about successive waves
- First graphic is for the region, the second specific to Thailand; slight differences reflect refinement of Thailand-specific analysis

Potential Warning Times for Full Conceptual Array



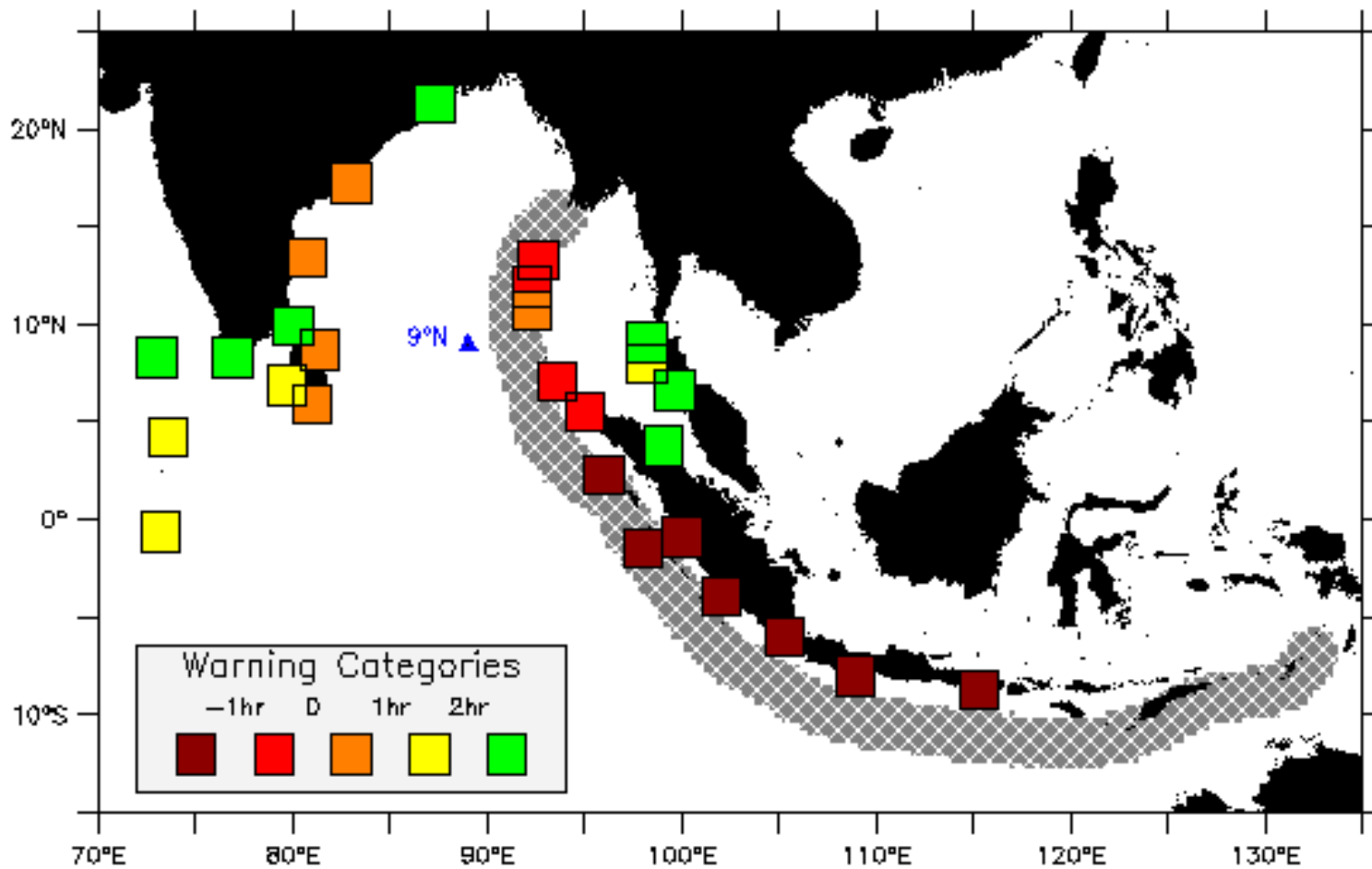
Potential Warning Times for Full Conceptual Array--Thailand



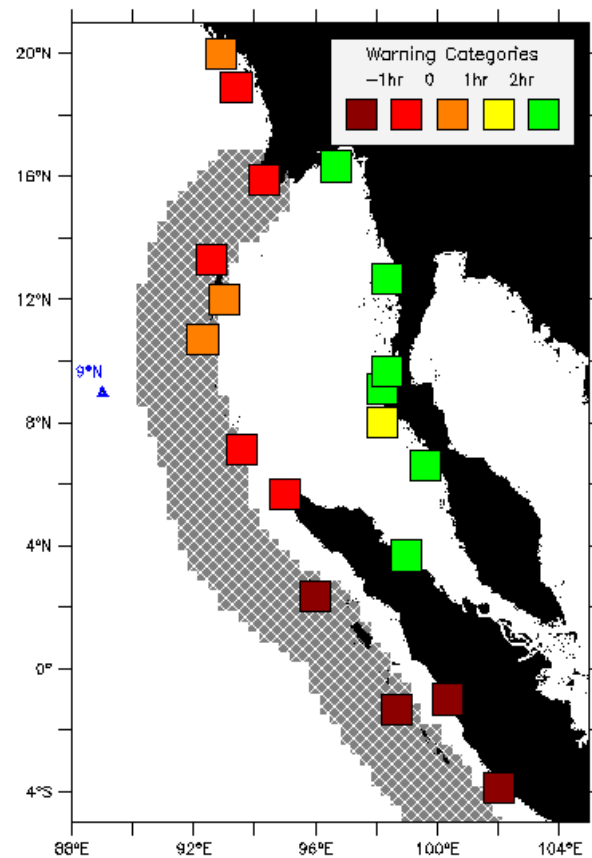
Single Station Deployment

- The following graphics depict potential warning times for single station deployments at 9°N, 4°N, 0°N, and 4°S
- For one station, 4°N appears to provide the greatest potential warning times for the region
- First graphic is for the region; second shows more detail for Thailand

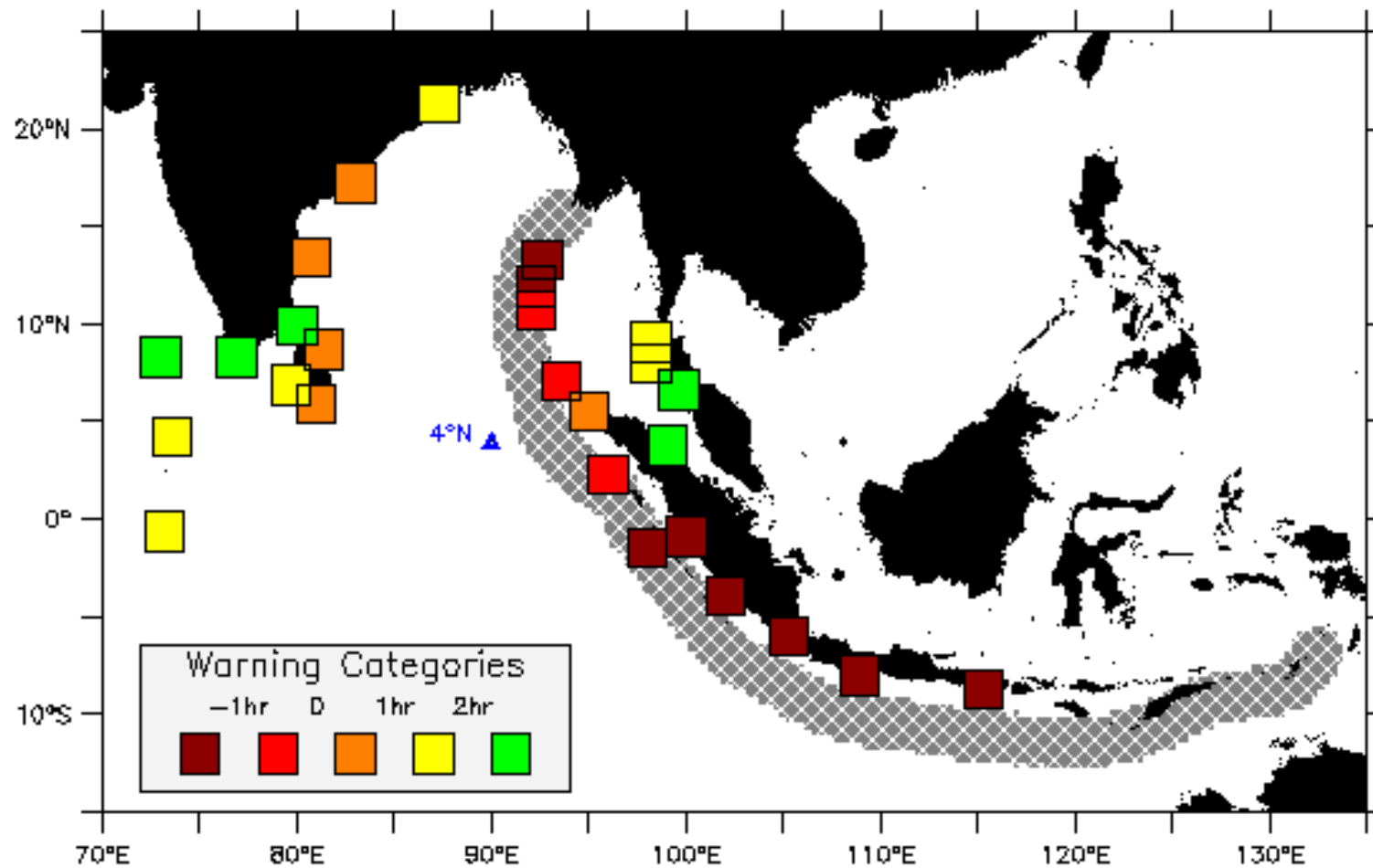
Single Station: 9°N



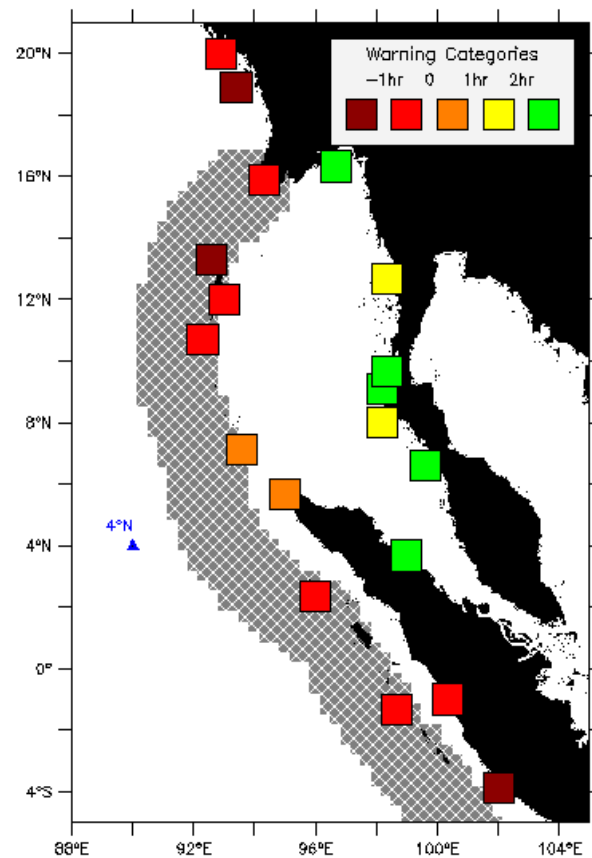
Single Station 9°N Thailand



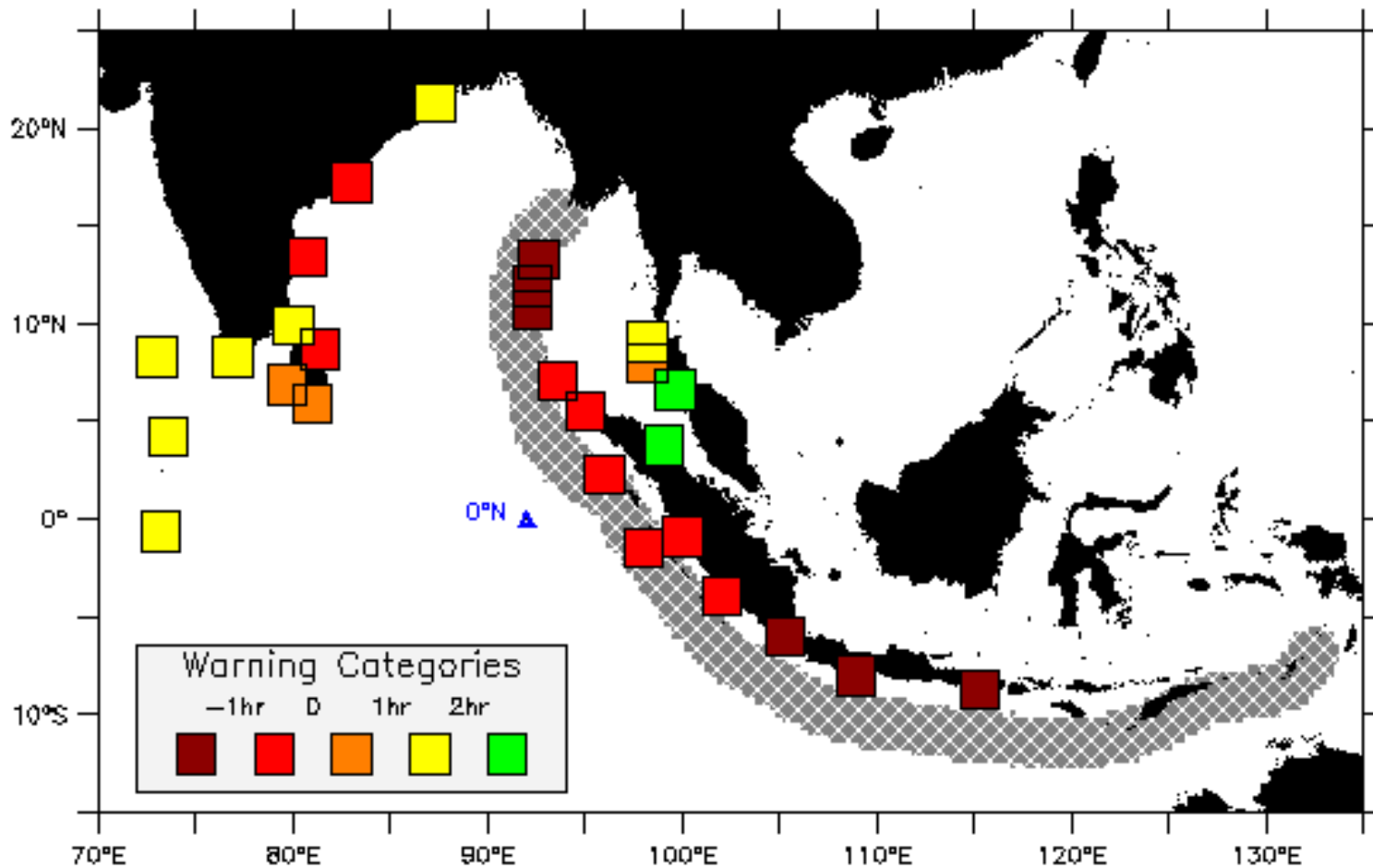
Single Station: 4°N



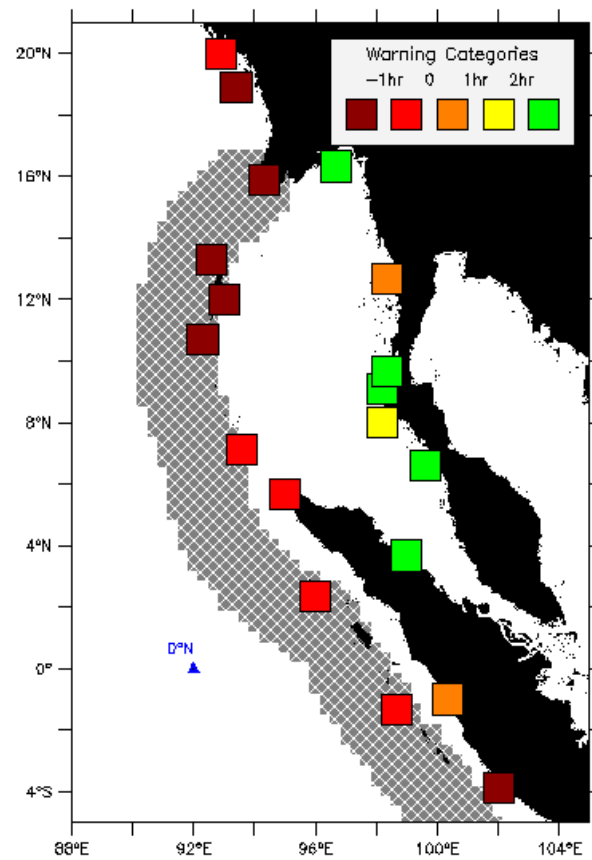
Single Station 4°N Thailand



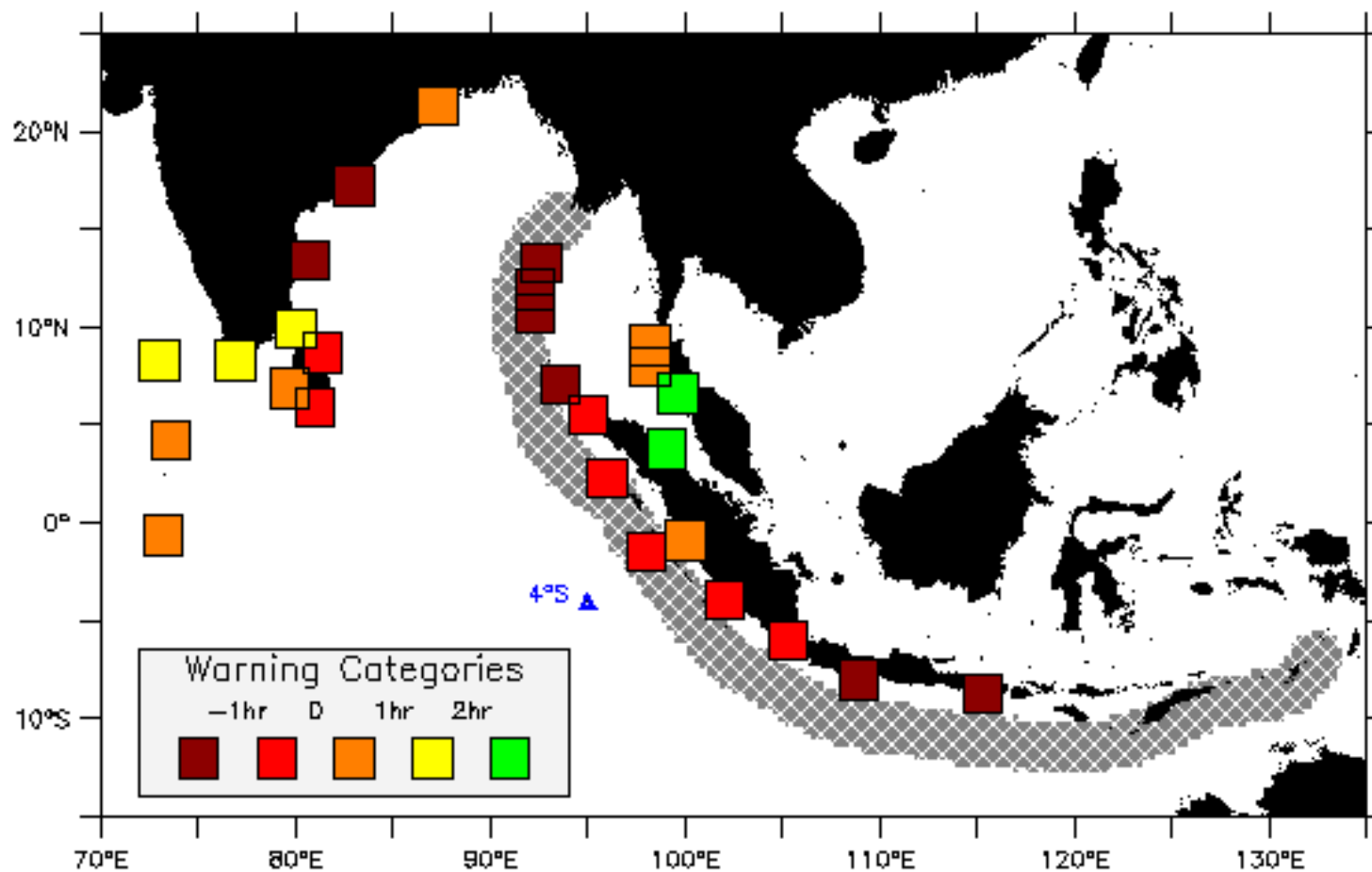
Single Station: 0°N



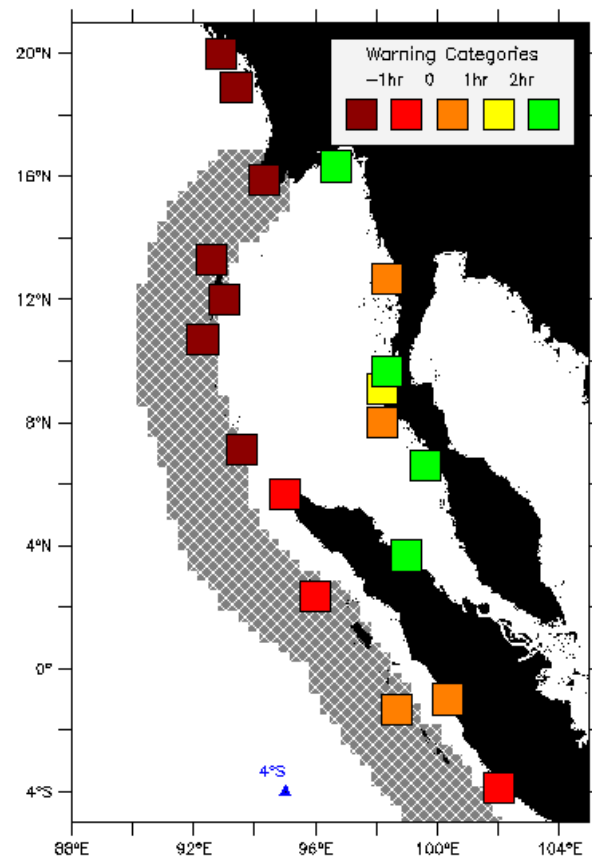
Single Station 0°N Thailand



Single Station: 4°S



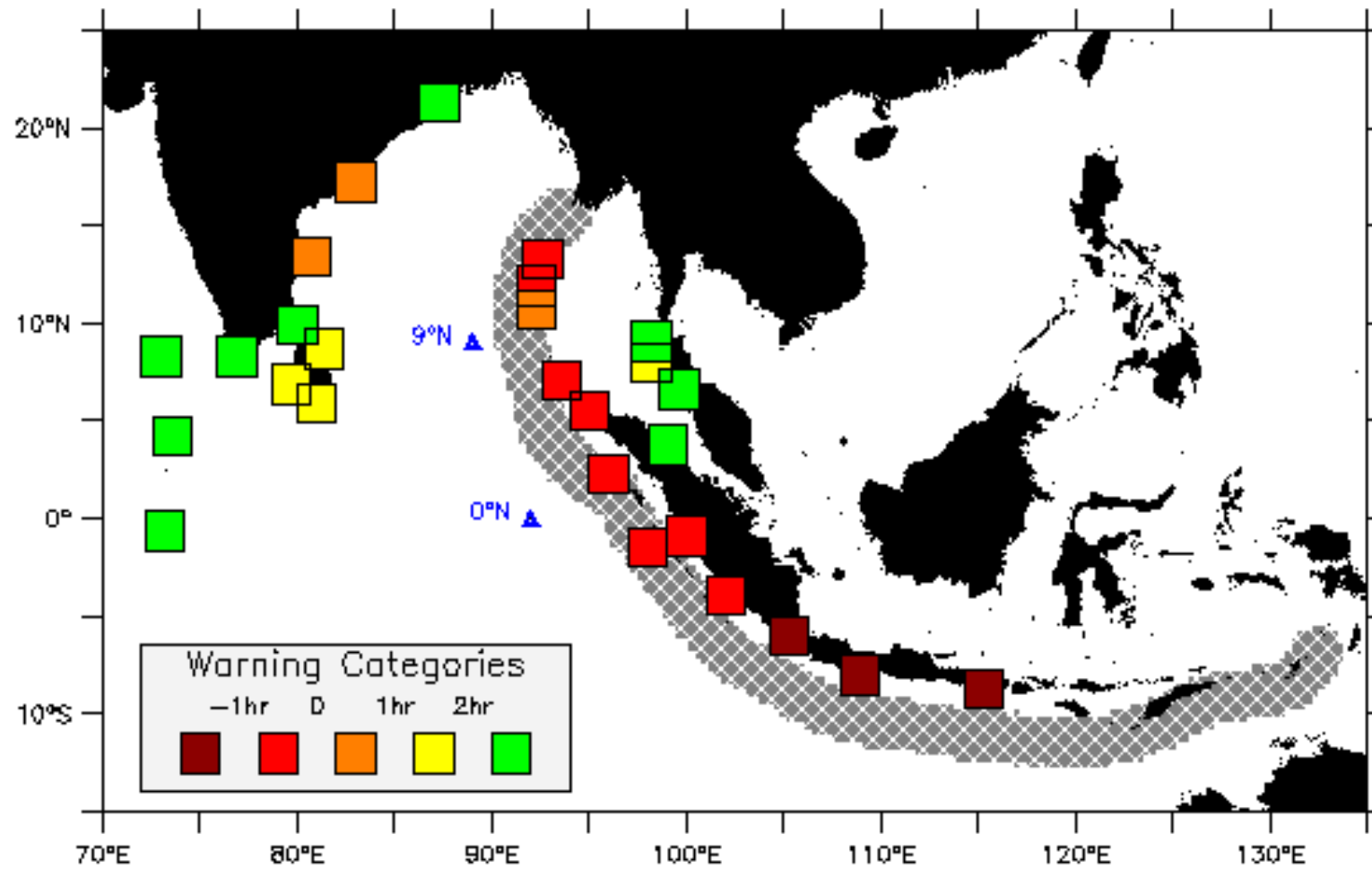
Single Station 4°S Thailand



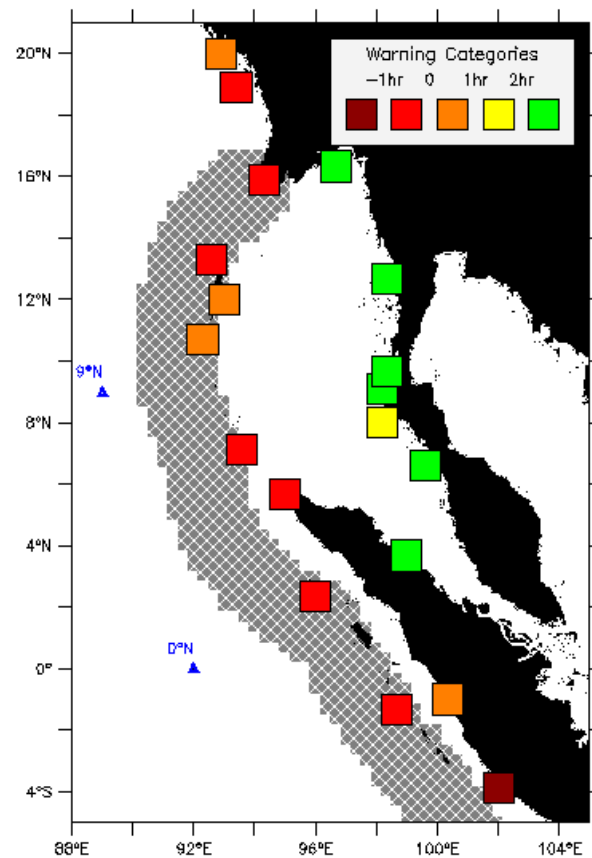
Two-Station Deployment

- For a two station deployment, sites at 9°N and 0°N offer the best overall potential warning times for the region
- Southern Sumatra and Java, however, would receive little warning from tsunami detection instruments at these locations.

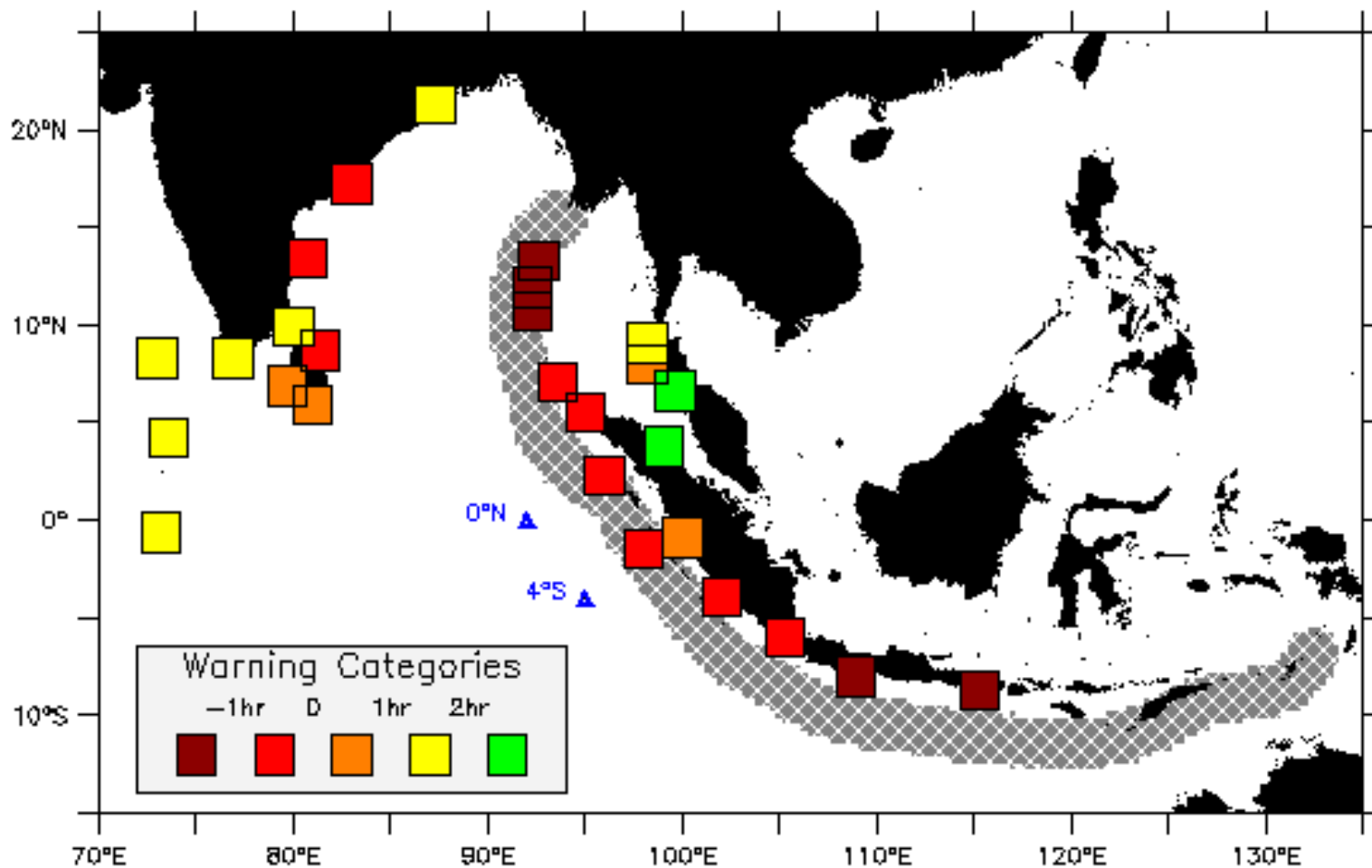
Stations at 9°N and 0°N



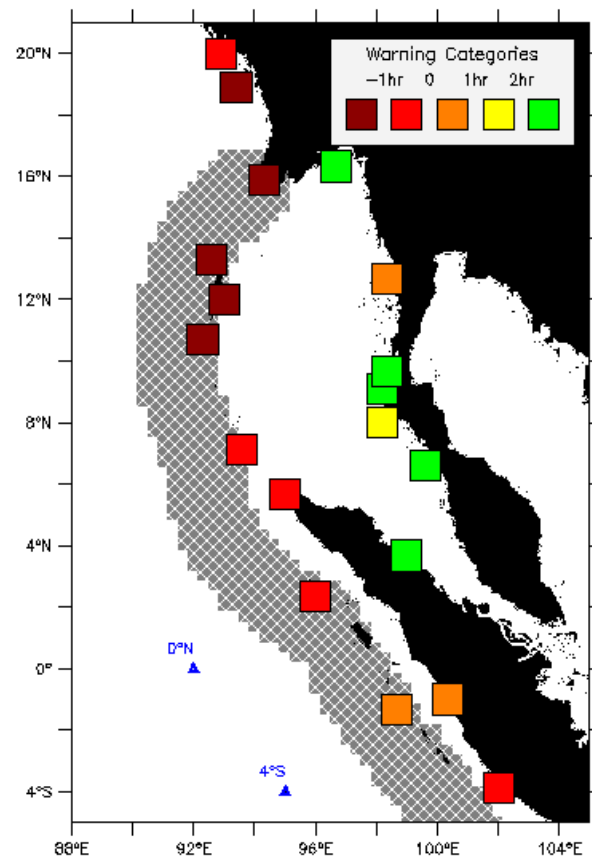
Stations at 0°N and 9°N Thailand



Stations at 0°N and 4°S



Stations at 0°N and 4°S Thailand

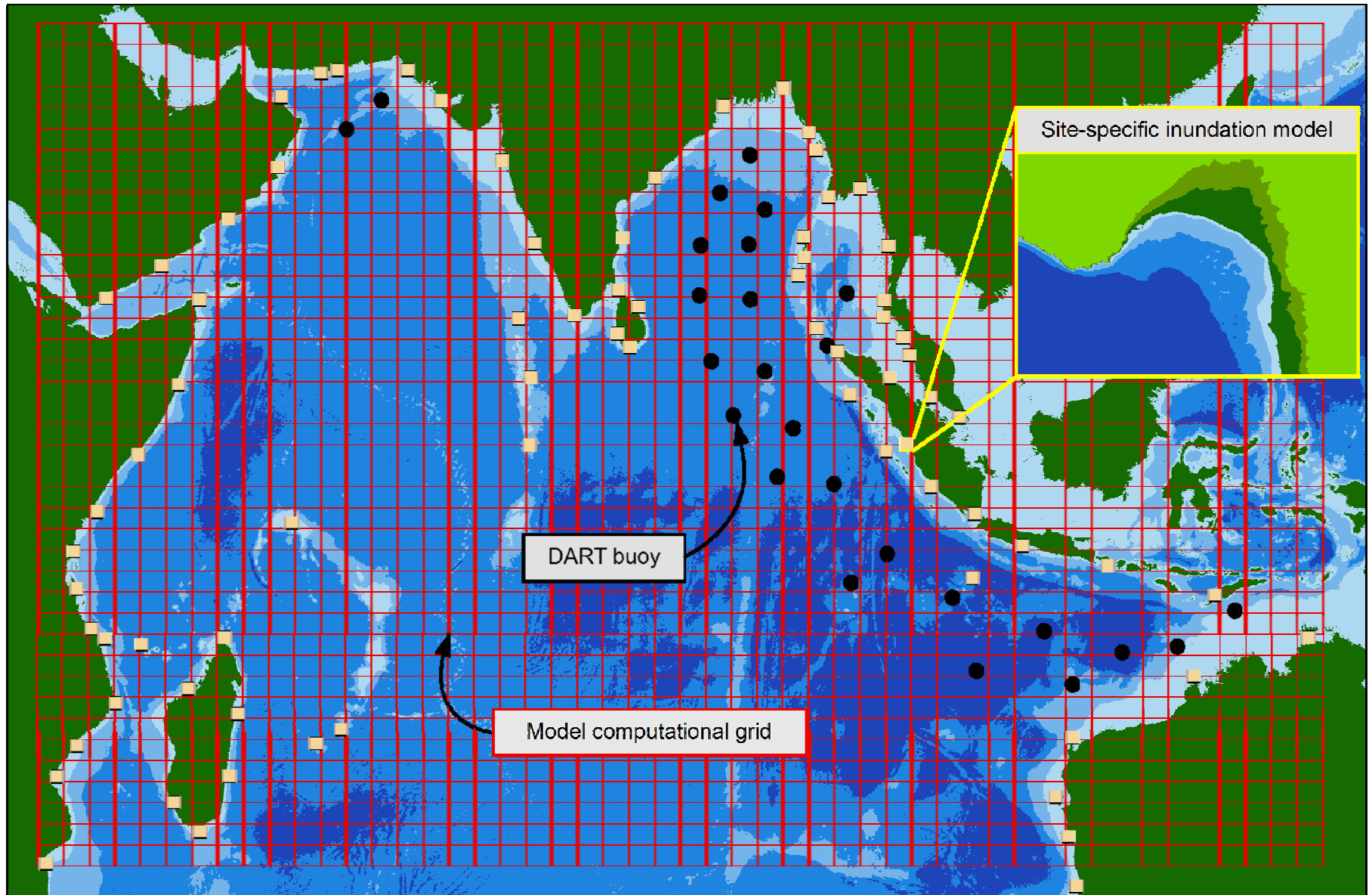


U.S. Proposed Option 1

- Deploy at 0°N 92°E between September and December 2006
- Deploy at 9°N 89°E between January and May 2007
- Provides best overall potential warning times for region by May 2007

U.S. Proposed Option 2

- Deploy at 4°N 90°E in late 2006, then at 9°N 89°E in early 2007
- Move station at 4°N to 0°N
- Provides best *interim* potential warning times
- More costly and difficult to implement



Conceptual Indian Ocean tsunami forecast system

Outcomes: ICG/IOTWS Working Group 2

1. Working Group 2 endorsement of USG proposal and recommendation that ICG/IOTWS-III (Bali, August 2006) adopt it
2. Encouragement for ICG members to engage the US IOTWS program and support deployments

Operations and Maintenance Considerations

- DART II Standard requires a 2 year buoy maintenance cycle (minimum) and a 4 year BPR maintenance cycle
- Contingencies include instrument failure, bio-fouling, vandalism, and other predicted and unpredicted events
- US is developing its approach to O&M support (Line Replacement Unit considerations, parts depot, technical support, etc.)

Operations and Maintenance Considerations

- For the US, ship time costs approximately USD 30,000 per day. Based on this and other costs, we estimate the US O&M cost per buoy per year to be some \$445K exclusive of labor
- Costs for Thailand could be lower (cost of ship, distance to buoy)
- Expertise required includes electronics technicians, mooring specialists, ocean engineers and others
- Contracting could be an attractive option